Influence of calf–cow contact during rearing on social competence and stress reactivity in calves

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Influence of calf–cow contact during rearing on social competence and stress reactivity in calves

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1. Summary

Influence of calf–cow contact during rearing on social competence and stress reactivity in calves

We investigated if dairy calves reared with cow-contact differ in their social behaviour and stress reactivity compared to calves reared without cow-contact. 69 calves from 29 farms (34 *with cow-contact*, 35 *no cow-contact*) were subjected to a combined isolation-novel object-confrontation test. Behaviour was observed and heart rate was recorded; saliva samples for cortisol analysis were taken before and after trials. Data were analysed using linear mixed effects models. Heart rate during isolation was higher in *no-contact* calves, but was similar to the heart rate of *with-contact* calves at the end of the trial (P=0.005). We found no effect of cow-contact on saliva cortisol concentration or behaviour during the isolation–novel object test. In the confrontation test, *no-contact* calves approached the unfamiliar cow more often than *with-contact* calves (P=0.002). Threatening behaviour of the cow caused *with-contact* calves reared to show submissive behaviour more often than *no-contact* calves (P<0.001). More *no-contact* calves did not show any response to agonistic behaviour of the cow compared to *with-contact* calves (P<0.001). We conclude that rearing with cow-contact affected the cardiac stress reaction and led to a more appropriate social behaviour compared with traditional rearing. Contact with adults early in life may promote social learning in calves that positively affects their integration into the dairy herd later in life.

dairy calves, alternative calf rearing, dam rearing, isolation, confrontation

2. Zusammenfassung

Einfluss des Kuh-Kalb-Kontakts auf Sozialverhalten und Stressreaktivität von Kälbern während der Aufzuchtphase

In der vorliegenden Feldstudie wurde auf 29 Milchviehbetrieben (mit Kuhkontakt n=14, ohne Kuhkontakt n=15) untersucht, ob der Kontakt zur Kuh Einfluss auf das Sozialverhalten und die Stressreaktivität von Milchviehkälbern hat. Mit 69 weiblichen Kälbern (34 *mit Kontakt*, 35 *ohne Kontakt*) wurde ein kombinierter Isolations-Novel Object-Konfrontationstest durchgeführt. Dabei wurde das Verhalten der Tiere beobachtet, die Herzfrequenz aufgezeichnet und die Cortisolkonzentration im Speichel gemessen. Die Daten wurden mit linearen gemischte Effekte Modellen analysiert. Die Herzfrequenz von *ohne Kontakt* -Kälbern war während der Isolation höher als bei *mit Kuhkontakt* -Kälbern (P=0.005). Im Verhalten während der Isolation und in der Speichelcortisol-Konzentration wurde kein Effekt des Aufzuchtsystems festgestellt. *Ohne Kuhkontakt*- Kälber näherten sich der Konfrontationskuh häufiger als *mit Kuhkontakt*-Kälber (P=0.002). *Mit Kuhkontakt*- Kälber reagierten auf Drohverhalten der Kuh häufiger mit Unterlegenheitsgesten (P<0.001), während bei

ohne Kuhkontakt- Kälbern eine erkennbare Reaktion auf ein Drohen der Kuh häufig ausblieb ($P<0.001$). Kälber mit Kontakt zu Mutter oder Amme zeigten demnach adulten Kühen gegenüber ein angepassteres Verhalten, was darauf hinweist, dass der längerfristige Kontakt zu Mutter oder Amme einen positiven Lerneffekt auf das Sozialverhalten von Milchviehkälbern hat.

Milchkälber, alternative Kälberaufzucht, muttergebundene Aufzucht, Isolation, Konfrontation

3. Eingereichtes Manuskript

Title: Influence of calf–cow contact during rearing on social competence and stress reactivity in calves

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Abstract

Separating calf and cow within 24 h after birth is common practice in dairy farms. Some dairy farms, however, practice a rearing system in which the calves are nursed by their dam or by foster cows. We investigated if dairy calves reared with dam or foster cows (calves with cow-contact) differ in their social behaviour and stress reactivity from calves reared without cow-contact. Sixty-nine female calves (34 with cow-contact, 35 without cow-contact) between 27 and 93 days of age were subjected to a combined isolation-novel object-confrontation test. With the isolation–novel object test, we aimed to assess their stress reactivity and fearfulness towards a novel object. Following the isolation–novel object test, we confronted the calves with an unfamiliar cow to assess if and how previous cow-contact influences their

social behaviour. During the tests, behaviour was observed directly and the heart rate was recorded continuously; saliva samples for cortisol analysis were taken before and after the trials. The heart rate during isolation was higher in calves reared without cow-contact, but was similar to the heart rate of calves reared with cow-contact at the end of the trial ($F_{2,95}$ = 5.69, P = 0.005). We did not find an effect of cow-contact on saliva cortisol concentration or behaviour during the isolation–novel object test. In the confrontation test, calves reared without cow-contact approached the unfamiliar cow more often than calves reared with cow-contact ($F_{1,27}$ = 12.22, P = 0.002). Further, threatening behaviour of the cow caused calves reared with cow-contact to show submissive behaviour more often than calves reared without cow-contact ($F_{1,26}$ = 16.94, P < 0.001). Accordingly, more calves reared without cow-contact did not show any visible response to threatening behaviour of the cow compared with calves reared with cow-contact ($F_{1,26}$ = 14.77, P < 0.001). We conclude that rearing with cow-contact affected the cardiac stress reaction but not the hypothalamic-pituitary-adrenal axis reactivity, and led to a more appropriate social behaviour compared with traditional rearing without cow-contact. Thus, contact with a dam or foster cow early in life may promote social learning in dairy calves that may positively affect their integration into the dairy herd later in life.

Keywords:

dairy calves, alternative calf rearing, dam rearing, isolation, stress reactivity, confrontation

1. Introduction

The separation of calf and dam within 24 h after birth is common in dairy production. Advantages for rearing a calf separated from its dam are higher amounts of saleable milk, easier handling of cow and calf, easier control of the calf's milk intake and possibly prevention of disease transmission from cow to calf (Edwards and Broom, 1982; Flower and Weary, 2001).

The contact with the mother or adult conspecifics in general affects the social development of juveniles (cattle: von Keyserlingk and Weary, 2007; humans: Meyer et al., 1975; Burchinal et al., 1997; marmosets: Takahashi et al., 2015; songbirds: White et al., 2002). Calves kept with their dams for 2 weeks were more interactive with conspecifics and showed a broader repertoire of social behaviours compared with calves that got separated from the dam within 24 h after birth (Flower and Weary, 2001). Calves reared with dam-contact for 2 to 3 months showed less abnormal behaviour like cross-sucking or tongue rolling (Fröberg and Lidfors, 2009; Roth et al., 2009) and were socially more active in a confrontation test than calves reared without dam-contact (Wagner et al., 2013).

Findings on the effect of cow-contact on stress reactivity are in a way contradicting. On the one hand, calves reared with cow-contact were found to be more active and tended to show lower cortisol levels directly after an isolation test but no difference in heart rate compared with calves reared without cow-contact (Wagner et al., 2013). On the other hand, calves reared with dam-contact showed an increased heart rate during isolation compared with calves reared without dam-contact (Roth (2008),.

Keeping cow and calf together is practiced much less in dairy farming than in beef cattle farming. Nevertheless, from an animal welfare point of view, the practice of rearing calves separated from adults deprives cows and calves of their species-specific behaviour (von Keyserlingk and Weary, 2007) and may result in impaired social learning and development of abnormal behaviours (Daros et al., 2014; Gaillard et al., 2014; Johnsen et al. *in Press*).

Some dairy farmers criticise the traditional way of rearing calves in dairy production due to calf morbidity, cross sucking, labour input in milk-feeding calves by bucket and animal welfare concerns; thus, they rear their calves together with dams or foster cows while milking the latter additionally (Zumbrunnen, 2011). Previous studies on dam rearing in cattle were mostly conducted on an experimental farm under standardised experimental conditions (Flower and Weary, 2001; Roth et al., 2008; Duve et al., 2012; Wagner et al., 2013; Johnsen et al., 2014). However, because management factors like housing conditions, feeding management, and human–animal relationship strongly affect the behaviour of the animals, including operational farms into the research on dam rearing is indispensable.

We thus investigated the effect of contact with the dam or a foster cow during the first 3 months of life on the social behaviour and stress reactivity in dairy calves in an on-farm study. We aimed to examine if results from previous studies on experimental farms can be confirmed on farms with various managements and therefore be generally accepted. If a rearing system with cow-contact affects social learning and stress reactivity positively, it may bring advantages for the calves' development and adaptability as a cow later on in life. For each calf, we performed an isolation test of 10 min including 5 min of a novel object test, followed by 10 min of confrontation with an unfamiliar cow. We predicted calves that were reared with cow-contact to show more motivation to re-join the herd, to be less fearful towards a novel object and to show social behaviours that are more appropriate than those of calves reared without cow-contact.

2. Materials and methods

Ethical approval to conduct the study was obtained from the Zurich Cantonal Veterinary Office, Switzerland (Approval No. 52/2014).

2.1 Animals and farms

This study was conducted between November 2014 and April 2015 on 29 dairy farms (with cow-contact, *n* = 14; no cow-contact, *n* = 15) in Switzerland and Germany. Farms were similar in total number of animals, housing system, barn size and geographic region (Table 1). All farms except 1 farm with cow-contact followed at least national standards for organic farming. A broad range of breeds was kept: Holstein, Simmental, Brown Swiss, Original Brown, Grey cattle, German Red, sometimes crossed with beef cattle. On all farms, calves were group housed after 1 to 21 days of life. When no cow-contact was provided, calves were separated from their dam within 24 h after birth, whereas calves on farms with cow-contact sucked their dam and/or foster cows for 30 up to 180 days. Contact with the dam or foster cows was either restricted to 15 to 60 min for 2 to 3 times per day (farms with restricted cow-contact, *n* = 11), or calves were kept together with at least some cows or had access to the cows' barn 24 h a day (farms with unlimited cow-contact, *n* = 3).

One to three female calves on each farm (*n* = 69; with cow-contact, *n* = 34; no cow-contact, *n* = 35) between days 37 and 95 of life were chosen randomly as subjects. For each calf, we performed an isolation test of 10 min including 5 min of a novel object test, followed by 10 min of confrontation with an unfamiliar cow.

2.2 Experimental design, test arena and experimental procedure

2.2.1 Pre-experimental procedure

Prior to the experiments, clinical examinations on the calves were conducted by a veterinarian (CB) to prove their state of health, and the calf's thoracic perimeter was measured using a measuring belt (ANImeter®,Albert Kerbl GmbH, Buchbach, Germany) to

estimate body weight. After the examination, calves were equipped with belts for heart rate measurements (Polar® S810i system, Polar Elektro Europe BV, Zug, Schweiz), and heart rate baseline values were registered in the home pen for 10 to 40 min.

2.2.2 Test arena

The experiments took place in a test arena of 14 (10–20) m^2. On 19 farms, the calving pen was used as test arena; on 10 farms, a test arena was installed outside the calves' home pens, with the distance to the cow barn ranging from 0 to 200 m (mean: 23 m) and the distance to the peer group ranging from 0 to 70 m (mean: 7 m). Visual contact with the cow barn and the peer group was prevented by visual covers, whereas acoustic contact with peers and cows was given. The floor of the test arena was covered with straw, except in 4 farms without littering (with cow-contact, *n* = 3; no cow-contact, *n* = 1).

2.2.3 Experimental procedure

2.2.3.1 Isolation and novel object test

Before calves were moved to the test arena, a first saliva sample (S0) was taken for cortisol measurements. The isolation test started after the calf entered the test arena and the gate was closed. After 5 min of isolation, a novel object (inflated ball, 50 cm in diameter, colours: yellow, pink, blue and transparent) was dropped into the test arena and left in there for 5 min. Then, the experimenter entered the test arena and removed the ball. Subsequently, the farmer led a cow into the test arena to confront the calf.

2.2.3.2 Confrontation

Following the isolation, each calf was confronted with an unfamiliar cow. According to the farmers' estimation, the test cows were high in rank. Thirty-nine cows (with calf-contact, *n* = 24; no calf-contact, *n* = 15) were horned, 30 cows (with calf-contact, *n* = 10; no calf-contact,

n = 20) were hornless. All cows were tested only once. They were walked from the barn to the test arena by the farmer.

When experimenter and farmer had left the test arena, the gate was closed and observation began. After 10 min, the cow was removed from the test arena, and the second saliva sample (S1) was taken from the calf. Then the calf was moved back to its home pen by the experimenter and the farmer. Five minutes after the second saliva sample, a third sample (S2) was taken. Fifteen minutes after the calf had entered the home pen, the last saliva sample (S3) was taken.

Due to rigorous escape attempts by 1 calf and 1 cow attacking a calf repeatedly (both from the treatment with cow-contact), 2 tests had to be abandoned. These trials were not included in any of the analyses.

2.3 Data recording

2.3.1 Behavioural observations

Behaviour was observed directly with continuous focal-animal behaviour sampling (Martin et al., 1993) using the software Interact® (Mangold International GmbH, Arnstorf, Germany) and a laptop (Lenovo X200, Intel® Core). Behaviour was always recorded by the same person (AR) according to a determined ethogram (Table 2).

Vigilance behaviour was not analysed because this behaviour seemed to be largely influenced by environmental factors (people, other animals and noise) that we were not able to control. The behaviours “fast movement” and “solitary play” (Table 2) could not be differentiated, so these behaviours were not considered in the analysis. Because of low incidence, we defined 2 outcome variables as a combination of single behaviours (“socio-positive interaction” = sniffing plus naso-nasal contact; “submission after threat” = submission plus moving away; Table 2). Concerning cow behaviour, we recorded frequencies of threats and approaches towards the calf, independent of the calf’s reaction.

2.3.2 Physiological measurements

2.3.2.1 Heart rate

The Polar® S810i system (Polar Elektro Europe BV, Zug, Schweiz) was used to measure the heart rate (Langbein et al., 2004; von Borell et al., 2007). A chest belt (elastic band), with 2 integrated electrodes and a radio transmitter between them, was fitted around the torso approximately 5 to 10 cm behind the forelegs. Electrode gel was used to ensure the contact between electrodes and the calf's body. The chest belt was fitted to the calf directly after it was clinically examined, and the baseline heart rate was recorded for 10 to 40 min while the calf was moving freely in its home pen. For recording in beats per minute (bpm), signals (heart beats) sent by the transmitter were received by an interface (basic station) and sent to the computer using the POLAR Team2 Pro software (version 1.3.0.3, 2010). A blinded person analysed the data by using the Polar Precision Performance SW Version (4.03.040 Polar Pro Trainer Equine Edition) software according to Langbein et al. (2004). For each test situation (isolation, test minutes 1–5; novel object, test minutes 5–10; confrontation, test minutes 10–20), we used 2 to 5 sequences with an error rate <10% of 1 min each. Due to high error rates in some tachograms, 8 calves (with cow-contact, n = 3; without cow-contact, n = 5) could not be included in the analysis, resulting in heart rate data from 59 calves.

2.3.2.2 Cortisol

All saliva samples were collected by inserting an absorbent cotton swab (Salivette®, Sarstedt AG, Nürnbrecht, Germany) into the calf's mouth with a forceps for 6 s. Samples were stored in a tube in the freezer (−20 °C) to prevent drying until analysis. For the analysis, the Salivette® tubes were defrosted at room temperature, and saliva was removed from the absorbent cotton by centrifugation (10 min at 2,500 *g*) (Wagner et al., 2014). Afterwards, the saliva was filtered (Milliex®-GP Filter, 0.22 µm, PES, Merck Millipore, Schaffhausen, Switzerland) and aliquots of the saliva samples were analysed using a cortisol enzyme immunoassay (Salivary Cortisol EIA, Salimetrics®, Suffolk, United Kingdom) by a laboratory

technician who was not aware of the research question. Samples of 2 calves (1 per rearing system) could not be included in the analyses because of insufficient saliva material. Due to technical problems, it was not possible to collect 4 saliva samples from all calves. In total, we took 239 samples, of which 116 originated from calves with cow-contact (S0: 31, S1: 31, S2: 28, S3: 26) and 123 from calves without cow-contact (S0: 34, S1: 34, S2: 34, S3: 21).

2.4 Statistical analysis

Statistical analyses were carried out in R, version 3.1.3 (R Core Team, 2015) using linear and generalised linear mixed-effects models (lme, package *nlme*; glmer, package *lme4*) to analyse the influence of the rearing system (factor with 2 levels: with cow-contact, without cow-contact) on social behaviour (frequencies/duration [s]), change in heart rate (difference of each sequence to the last baseline sequence [bpm]) and change in cortisol concentration (difference of each sample to the baseline sample [ng/ml]). Further explanatory variables and their 2-times interactions were included, such as calf's age (continuous) and horn status of the cow (factor with 2 levels: horns, no horns). In the models evaluating heart rate and cortisol, the test situation was included additionally (factor with 3 levels: isolation, novel object, confrontation). Individual nested in farm was included as random effect in all models evaluating behaviour, and for heart rate and saliva cortisol we considered the phase within trial as additional random effect.

The full models were reduced in a step-wise backwards approach with a 5% significance level as a threshold for exclusion of explanatory variables from the model. We examined the assumptions of normally distributed errors and homoscedasticity graphically with the use of the Normal plot (residual quantiles versus quantiles of a normal distribution), the Tukey–Anscombe plot (residuals versus estimates), and plots of the residuals versus explanatory variables. This graphical analysis of the residuals showed that some of the outcome variables needed to be log transformed (fast locomotion, solitary play, socio-positive interactions), logit transformed (proportion of submissive reactions after threat and proportion

of no reaction after threat) or dichotomised (elimination, escape attempts, withdrawal from the novel object). Calves from the farm where the test arena was more than 200 m away were excluded from the analysis of the physiological parameters due to the long duration of movement on the way to the test arena. One calf (with cow-contact) had to be excluded from the cortisol analysis as an outlier.

3. Results

3.1 Physiological parameters

3.1.1 Heart rate

The differences in heart rate values between isolation and baseline were smaller and, accordingly, the decrease in heart rate over the course of the trial was less pronounced in calves reared with cow-contact compared with calves reared without cow-contact (interaction rearing system × test phase: $F_{2,95} = 5.69$, $P = 0.005$; Fig. 1). Over the course of the trial, the heart rate did not return to baseline values. Baseline values were not significantly affected by the rearing system (Table 3).

3.1.2 Saliva cortisol

We found no significant effect of either rearing system ($F_{1,25} = 2.10$, $P = 0.159$) or test phase ($F_{1,95} = 3.31$, $P = 0.072$) on the difference between test value and baseline value in cortisol concentration (Table 3).

3.2 Behaviour

3.2.1 Isolation test

Calves explored more during the isolation than during the confrontation test (duration: $F_{1,67} = 62.22$, $P < 0.001$; Table 4), but there was no effect of the rearing system ($F_{1,27} = 0.14$, $P = 0.709$). Further, no effect of the rearing system was found on the number of vocalisations ($F_{1,27} = 0.95$, $P = 0.339$), number of escape attempts ($\chi^2_1 = 0.05$, $P = 0.818$), elimination

frequency (χ^2_1 = 0.01, P = 0.922), duration of fast locomotion ($F_{1,27}$ = 1.43, P = 0.294) and solitary play frequency ($F_{1,27}$ = 0.23, P = 0.638).

3.2.2 Novel object test

Older calves tended to get more often in contact with the novel object compared with younger calves ($F_{1,39}$ = 3.28, P = 0.078), but there was no difference between calves reared with cow-contact and calves reared without cow-contact ($F_{1,27}$ = 0.69, P = 0.415). We did not find an effect of the rearing system on the frequency of withdrawal from the object (χ^2_1 = 2.21, P = 0.137).

3.2.3 Confrontation

There was no effect of the rearing system on the number of threats shown by the cow ($F_{1,37}$ = 0.10, P = 0.757; no cow-contact, n = 178; with cow-contact, n = 139) or the number of calf-directed approaches ($F_{1,27}$ = 0.08, P = 0.783; no cow-contact, n = 66; with cow-contact, n = 39). Nine cows (no cow-contact, n = 5; with cow-contact, n = 4) never showed threatening behaviour, and 24 (no cow-contact, n = 11; with cow-contact, n = 13) approached the calf during the confrontation test. Dehorned cows approached younger calves more often than older calves, whereas horned cows approached older calves more often than younger calves (interaction age × horn status: $F_{1,36}$ = 12.60, P = 0.001). Horn status did not influence the number of threats by the cow ($F_{1,36}$ = 1.93, P = 0.173).

Cows tended to show threatening behaviour more often with increasing age of the calf ($F_{1,38}$ = 3.76, P = 0.060). Threatening behaviour shown by the cow was not affected by the rearing system ($F_{1,37}$ = 0.10, P = 0.757). However, calves reacted clearly differently to threats by the cow: calves reared with cow-contact showed submissive behaviour more often than calves reared without cow-contact ($F_{1,26}$ = 16.94, P < 0.001; Fig. 2a). Accordingly, calves reared without cow-contact more often did not show a visible response to a cow threat than calves reared with cow-contact ($F_{1,26}$ = 14.77, P < 0.001; Fig. 2b).

Calves reared without cow-contact approached the cow more often than calves reared with cow-contact ($F_{1,27}$ = 12.22, P = 0.002). With increasing age, calves approached horned cows less often compared with hornless cows, whereas the calf's age did not affect the frequency of approaches towards hornless cows (interaction age × horn status: $F_{1,36}$ = 13.75, P = 0.001). The rearing system had no effect on the number of socio-positive interactions during confrontation ($F_{1,27}$ = 0.85, P = 0.365).

Further, the frequency of nursing bouts was not affected by any of the tested variables (rearing system: $F_{1,27}$ = 0.36, P = 0.555). In total, 20 calves showed udder-directed search movements (no cow-contact, n = 8; with cow-contact, n = 12).

4. Discussion

4.1 Physiological parameters

4.1.1 Heart rate

Our results support earlier findings that social separation induces a physiological stress response in calves (Hofer and Shair, 1987; Hopster and Blokhuis, 1994; Boissy and Le Neindre, 1997). Although physical activity (e.g. locomotor behaviour, muscle tension) leads to an increase in heart rate (Rushmer and Smith, 1959; MacArthur et al., 1979; Baldock et al., 1988; Stratton et al., 1994), there were no treatment effects on exploration, locomotion and play behaviour in our study. We thus conclude that the steeper increase in heart rate in calves reared without cow-contact than in those reared with cow-contact was probably triggered by emotional arousal (Briefer et al., 2015). Rearing with cow-contact often includes a more complex environment than rearing without cow-contact, e.g. calves having access to the dairy barn and large calf areas to which cows get access for suckling. Thus, relocation to an unknown surrounding might be more stressful for the calves reared without cow-contact because they are usually kept in a single-room calf area.

Contrary to our findings, Roth (2008) found higher heart rates during isolation in calves reared with dam-contact compared with calves reared without dam-contact, whereas Wagner et al. (2013) did not detect such differences in experiments using the same test arena as Roth (2008). However, these experiments were carried out on just one experimental farm by using a small test arena placed on concrete with wooden walls preventing any visual perception of the surroundings. In contrast, we used a littered calving pen that offered plenty of space on most farms.

We found a decline in the calves' heart rates when the unfamiliar cow was entering the test arena. This finding is in agreement with Boissy and Le Neindre (1997), who showed a decline in heart rate induced by the entrance of conspecifics after an isolation in heifers. Thus, a conspecific, regardless of its identity, can buffer the stress response. However, we note that we cannot differentiate between a time and a situation effect because the duration

of test was confounded with the test situation (isolation, confrontation), with confrontation always following isolation.

4.1.2 Cortisol

We found no effect of the rearing system on the hypothalamic-pituitary-adrenal axis reactivity. This is in contrast to findings in heifers that had been reared with and without cow-contact, in that the cortisol response to isolation was lower in dam-reared heifers compared with heifers that had been reared without dam-contact (Wagner et al., 2014). However, in a follow-up study on the same experimental farm, this effect could not be repeated (Kälber et al., 2014).

4.2 Behaviour

4.2.1 Isolation and novel object

There was no effect of the rearing system on the behaviour of the calves during isolation. In a previous study, dam-reared calves showed more escape attempts during isolation and were more active than calves reared without dam-contact (Wagner et al., 2013). The authors interpreted this behaviour as a higher motivation to re-join the herd or peer group. Furthermore, dam-reared calves struggled less during restraint than calves housed singly or in pairs (Duve et al., 2012).

However, the studies by Wagner et al. (Wagner et al., 2013) and Duve et al. (2012) differ from our study in several ways. First, our test arena during isolation was substantially bigger, and we observed almost no flight attempts by the calves. Second, there was a much larger variability concerning suckling management on farms with cow-contact compared with the study by Wagner et al. (2013), where all calves had unrestricted contact with their dams. In our study, the cow-contact was either restricted or unrestricted, and contact was provided with either the dam or a foster cow.

Newberry and Swanson (2008) suggested that restricted cow-contact, including daily separations of cow and calf, could be beneficial because it may encourage the development of the calf's social independence from the dam. Previous studies (Roth et al., 2009; Veissier et al., 2013) compared restricted and unrestricted contact with the dam with regard to weight gain. Veissier et al. (2013) showed that calves with restricted cow-contact had high weight gains not only pre-weaning but also post-weaning, which they attributed to the fact that these calves were less dependent on the dam. In contrast, the study by Roth et al. (2009) found dam-reared calves to show higher weight gains pre-weaning but not post-weaning compared with calves fed 8 L milk per day, probably because rumen development was retarded due to intake of large amounts of milk in dam-reared calves. Accordingly, dam-reared calves were heavier than artificially reared calves although they had a reduced weight gain shortly after weaning.

Rearing dairy calves in complex social environments was found to reduce food neophobia (Costa et al., 2014) and rearing mice in enriched environments led to more novel object-contacts (Misslin and Ropartz, 1981). We thus expected calves reared with cow-contact to be less fearful towards a novel object than those reared without cow-contact (Wagner et al., 2014); however, we found no differences between rearing systems in the frequency of approaches towards the ball or that of withdrawals from the ball. Instead, older calves tended to contact the ball more often than younger ones, regardless of the rearing system. Similarly, Lauber et al. (2006) found a decreased latency to interact with a novel object and an increased number of interactions with the novel object in calves with increasing age. With increasing age, calves may have experienced a number of new situations or unfamiliar objects, leading to less fearfulness towards novelty.

4.2.2 Confrontation

Calves reared without cow-contact approached the cow during confrontation more often than calves reared with cow-contact. In the first hour after birth, cow–calf contact mainly includes

licking and contact calls and suckling(Newberry and Swanson, 2008). Licking and contact calls, and sometimes some suckling, can be experienced even in rearing systems with separation of cow and calf, e.g. when calving happens during the night and separation the next morning. Consequently, calves reared without further cow-contact may associate adults with positive experiences early after birth. On the other hand, growing up with regular contact with adult cows means experience of a broad range of interactions with the dam and other adults, including agonistic behaviours like threats and displacements (Waiblinger et al., 2013). Such experience could be a reason why calves reared without cow-contact were less cautious than calves reared with cow-contact when being confronted with a cow. Accordingly, calves reared without cow-contact often failed to show any visible reaction to a cow's threat. Calves are presumed to be lower in rank than cows, and thus submissive behaviour towards a cow would be the appropriate behaviour (Reinhardt, 1980). Calves reared with cow-contact indeed reacted mostly with submissive behaviour after a cow's threat. Similarly, Wagner et al. (2012) found that dam-reared heifers were more often submissive during integration into the cow herd compared with heifers reared without dam-contact. These findings indicate that calves reared with cow-contact may have learned to understand social signals of conspecifics and to react in an adaptive way, as submissive response to threats of adult conspecifics may reduce the number of aggressive interactions. Even though opportunities for the calf to learn social communication may be limited in restricted-contact systems, the restricted cow–calf contact seemed to be beneficial for social development compared with no contact. Thus, contact with the mother and/or adult cows in general may affect early social learning, which might prepare the calves for the social challenges, e.g. during integration into the dairy herd, later in life.

5. Conclusion

Calves that had contact with the dam or a foster cow during the rearing period showed a more adaptive social behaviour in response to agonistic signals shown by an unfamiliar cow

compared with calves reared without cow-contact. This finding indicates that cow–calf contact improves the social development in calves, emphasizing the importance of contact with the dam or a foster cow even if this contact is restricted in time.

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Table 1:

Number of cows, number of calves (up to 3 months old), space allowance per calf in the calf area (mean and range)

Farm characteristics	Rearing system	
	no cow-contact	with cow-contact
Number of cows	42 (14–103)	41 (9–90)
Number of calves	8 (2–25)	9 (1–26)
Area per calf (m^2)	5.6 (2.0–12.0)	6.0 (1.7–20.3)*

* numbers of five farms where calves were kept with the cows in the cow barn are missing

Table 2:

Description of the recorded behaviours during isolation, novel object (NO) and confrontation tests, in frequency (F) and duration (D)

	Description of recorded behaviour		
ISOLATION AND NOVEL OBJECT	Exploration	Sniffing or licking on floor, wall or fence	F, D
	Vigilance	Fixed head position above or below the horizontal to the withers, ears upright and gaze directed straight ahead	F
	Vocalisation	Any vocalisation by the calf	F
	Elimination	Micturition and defecation	F
	Escape attempt	Calf is jumping and/or trying to get over or through the fence/wall (Wagner et al., 2013)	F
	Fast locomotion	Includes trotting (2-beat gait), cantering (3-beat gait)	F, D
	Solitary Play	Locomotor play (i.e. jump, kick, buck) and object play (i.e. butting objects), according to (Jensen et al., 1998)	F
	Contact with NO	Calf is touching the ball with its nose/mouth or forehead	F, D
	Withdrawal from NO	Head and gaze towards the ball and jerky movements backwards	F
CONFRONTATION	Head butting	Calf is butting towards the cow's belly region	F, D
	Approach	Initiator approaches the recipient, head above the horizontal to the withers	F, D
	Sniffing	Nose and mouth are approaching and touching the recipient's body	F
	Naso-nasal contact	Noses of both individuals are touching each other	F
	Threatening	Initiator is presenting the forehead with inclined head, without touching the recipient	F
	Butting	Initiator is butting the recipient with its head (forehead or nose)	F
	Submission	Recipient lowers its head below the horizontal to the withers, chin outstretched	F
	Moving away	Recipient is moving away or changing the position, usually fast	F
	No reaction	No visible reaction of the recipient to threatening, butting or approach	F

Table 3:

Median (min.–max.) of heart rate (bpm) and saliva cortisol (ng/ml) depending on test phase and rearing system

Test phase	Rearing system	
	with cow-contact	no cow-contact
	heart rate (bpm)	
Baseline	115 (85–164)	110 (64–159)
Isolation (min 1–5)	141 (91–211)	160 (111–203)
Novel object (min 5–10)	133 (84–201)	145 (91–194)
Confrontation (min 10–20)	131 (88–211)	134 (101–225)
	cortisol (ng/ml)	
Baseline (S0)	0.322 (0.003–1.126)	0.189 (0.000–0.895)
End of trial (S1)	0.580 (0.064–1.363)	0.383 (0.026–1.088)
5 min after S1 (S2)	0.469 (0.161–1.534)	0.413 (0.000–1.550)
15 min after re-joining group (S3)	0.590 (0.086–2.532)	0.441 (0.127–1.136)

Table 4:

Median (min.–max.) of recorded behaviour, in frequency (F; events per 5 or 10 min) or total duration (D; s)

Behaviour of the calf	Rearing system	
	with cow-contact	no cow-contact
isolation–novel object test		
Elimination (F)	0.5 (0–3)	1.0 (0–2)
Exploration (D)	247.2 (77.9–497.1)	230.0 (20.8–502.9)
Escape attempt (F)	0.0 (0–5)	0.0 (0–6)
Vocalisation (F)	5.5 (0–51)	11.0 (0–46)
Solitary play (F)	0.0 (0–19)	0.0 (0–14)
Fast locomotion (D)	1.08 (0–60.9)	2.96 (0–88.6)
Contact with novel object (F)	4.0 (0–12)	5.0 (0–12)
Withdrawal from novel object (F)	0.0 (0–3)	1.0 (0–2)
confrontation		
Approach (F)	2.0 (0–6)	6.0 (0–16)
Socio-positive interaction (F)	1.0 (0–7)	0.0 (0–6)
Submissive after threat (F)	4.0 (0–10)	2.0 (0–8)
No reaction after threat (F)	0.0 (0–1)	2.0 (0–10)
Nursing bouts (F)	0.0 (0–1)	0.0 (0–1)

Figure captions

Fig. 1: Difference of heart rate to the baseline depending on the test phase and rearing system (light grey: no cow-contact, dark grey: with cow-contact). Raw data are presented as box plots indicating observed median, first and third quartiles, and absolute range of data.

Fig. 2: Proportion of submissive behaviour shown by calves after threat by the cow, and number of approaches towards the cow depending on the rearing system. Raw data are presented as box plots indicating observed median, first and third quartiles, and absolute range of data.

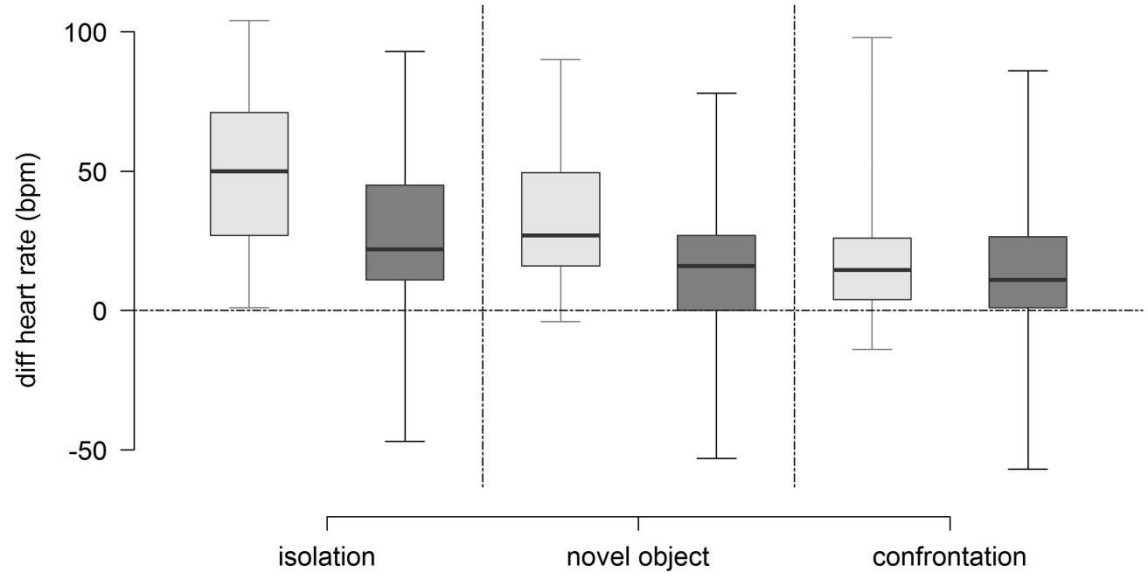
100
50
0
-50
diff heart rate (bpm)
isolation
novel object
confrontation

Fig. 1

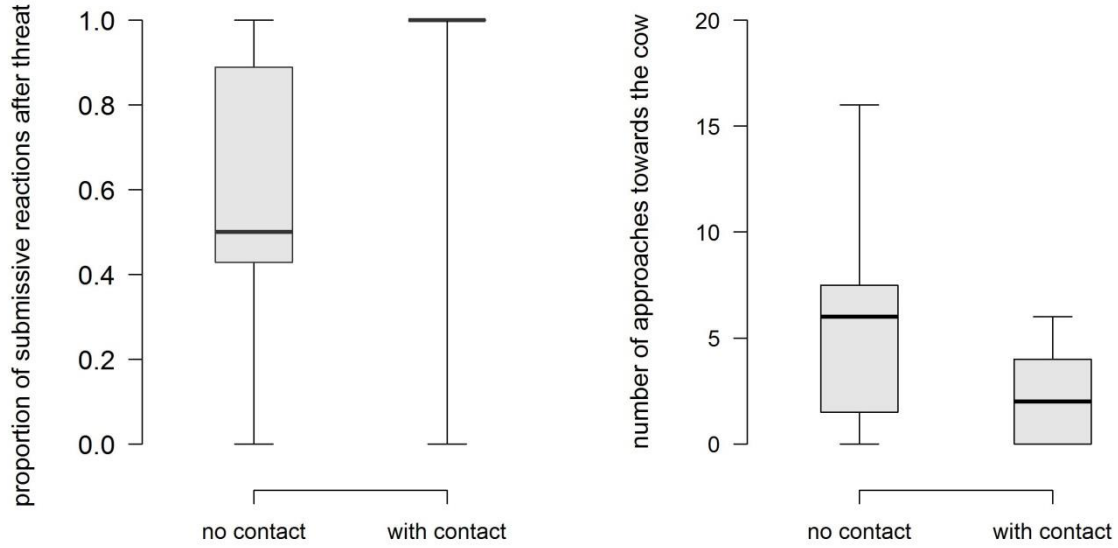
1.0
0.8
0.6
0.4
0.2
0.0
proportion of submissive reactions after threat
no contact
with contact
20
15
10
5
0
number of approaches towards the cow
no contact
with contact

Fig. 2

5. Anhang: zentrale Aussagen

Vom Journal gefordert, bei Manuskript-Einreichung

Highlights

- Calf welfare is supposed to be improved when reared with cow-contact.
- Calves with cow-contact reacted more appropriate to agonistic behaviour of a cow.
- Rearing with cow-contact affected the calves' cardiac stress reaction.
- Cow–calf contact improves social development in calves.